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A comparison between written and digital communication and the effect on the dental appliances constructed.

Hedieh Saraei

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Name Hedieh Saraei
Student number 1602730
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Supervisor Dr. Nikolaos Poulis
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Signature……

Abstract

- **Introduction:** Communication as a concept should be thoroughly studied as nearly all organisational schemes include some form of communication. Hence, a lack of effective communication between the members can majorly impact the efficiency and the overall success of the organisation. This is especially true in the field of dentistry, as the methods in which dental clinicians and technicians communicate with each other can highly impact the quality of the constructed dental appliances. The aim of this literature review was to compare written and digital means of communication between dental clinicians and technicians and examine its effect on the dental appliances constructed.
- **Materials and Methods:** A literature search was performed using databases such as PubMed, ScienceDirect, WileyOnlineLibrary and Discover@Bolton. The keywords used included the following: communication, dentist, technician, written, digital. The searches were limited to articles in English, published from 1960 to 2018.
- **Results:** It was found that the majority of the research evidence reported that there are ongoing communication issues between dental clinicians and dental technicians when written means of communication are used. Therefore, alternative methods such as incorporating digital means of communication can enhance the quality of the interactions between the said parties which can lead to improvements in appliance construction.
- **Conclusions:** The conducted research led to the conclusion that digital means of communication such as digital cameras, oral scanners, CAD-CAM, etc. can lead to a much more accurate and thorough exchange of information between dental

clinicians and dental technicians. This can in turn lead to better appliance construction.

Acknowledgement

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1.0 Introduction

1.1 Definition of Communication

The concept of communication can be explained as a system of signals which needs signals to be systematically encoded and appropriately decoded. For communication to be considered as skilled, the signal sent and received must be the same, regardless of the system of signals used e.g. language, pictures etc. (Dougall et al., 2008]. The study of communication is of significant importance and should be thoroughly studied as nearly all organisational schemes include some form of communication. Therefore, it can be suggested that a key factor which can negatively impact the success of an organisation is a lack of effective communication amongst its members (Darcis, 2016).

1.2 Communication in the past

The first ever method of communication between individuals was the human voice where sounds were generated to express feelings. Long-distance forms of communication which were not based on words such as the smoke signals used by American Indians were also developed as a common means of communication. However, such methods were just equipped for exchanging restricted signs for example ‘danger’. Additionally, messages carved on stone pillars were a technique for communication across time. Nonetheless, such messages could only be seen within the reading range. Messengers were likewise used to convey essential messages from a spot to another. However, the speed of this procedure depended on how fast the person could travel. Carrier Pigeons were also used a means of exchanging messages during World War one

and World War two specifically. This communication strategy was the world's quickest communication system framework in the dark and middle ages (Richard, 2016).

1.3 Communication methods of the present and future

With the invention of the first telephone, the process of communication became a lot easier. Nonetheless, in the initial days, people had to travel to a central point to make and receive calls. In 1901, the radio was invented which was a major life line of information for the masses during World War II. Later, the invention of the television became the dominating form of mass-communication technology. As time went on, cell phones were invented which enabled people to send instant messages to one another. The internet was invented next which is now the latest method of communication. These days, smart phones can provide internet access which can enable fast communication between people as well as provide the usage of social media networks such as Facebook, Instagram etc. Such applications (apps) have now made it possible for individuals to communicate with their friends/ family at the touch of their fingertips via pictures/texting etc. Additionally, apps such as Skype which provide video calls have now made it possible for people to see each other no matter how far away they are from each other. Therefore, we have come a long way since the beginning days of communication and today's communication methods are more advanced than ever (Darcis, 2016). Currently, new ideas and values are being broadcasted to all around the world through mass media and international communication networks. Therefore, we can make the statement that the evolutions made in the communication sector provide the world with guidance. When something happens in one part of the world e.g. a presidential election, it can easily and instantly be expanded to each part of the world through mass means of communication.

Mass media has the capability to create new aspects in the process of communication. Through utilising mass media, which has now become a major part of the human day-to-day life, we can now attain information on any occurrences which takes place in any part of the world and have our own input and interpretation on them. Communication as a huge market, also elevates both manufacturing and consuming levels of market products and gives direction to the economy of the world. This has become a massive topic of historical, economic and cultural research from broadcasting to shows on TV, documentaries and propaganda. In addition, new communication technologies and methods have brought about changes into various aspects of the human life, for example, in the way humans can have interactions with each other and form relationships with one another (Büyükbaykal, 2014). Various types of ideas for future communication exists, but we cannot be absolutely sure of what may come next. However, in far off future, humans may be able to transfer their thoughts through a network directly into the brain of another individual (Darcis, 2016). Currently the main forms of communication between individuals include written and digital communication.

1.4 Written Communication

Written communication can be defined as interaction via any written document e.g. letters, notes, reports, memos etc. As shown in surveys of stakeholders from higher education and the workforce, written communication is commonly viewed as one of the most critical capability an individual can possess to be successful in their academia and career. The majority of the bosses also view written communication skills as being one of the most important job skills an employee can possess. Therefore, if one has the skill

to write clearly and adequately, such a skill can highly benefit them in their career (Richard, 2016).

1.5 Digital Communication

Digital communication is when information is digitally encoded as specific signals and transferred electronically to the recipients with the data transfer level depending upon its characteristics. This form of communication can be done over far ranges via internet and provides features such as enabling conferences to be held through video calls. This can help save a huge amount of time, effort and money. The utilisation of digital based communication methods in the dental setting is now very prevalent. For example, 90% of the population in the United Kingdom now own a cell phone. In addition, the National Health Service (NHS) is now utilising digital communication methods for communicating between clinicians and patients, for example through email and text messages (Huxley et al., 2015). In addition, as briefly mentioned above, digital methods of communication like messaging apps are also becoming more and more popular worldwide. The life of an average human being is becoming more and more digital and we as humans are spending more time on our digital devices such as our cell phones. This is especially prevalent in most young people and the older population are also catching up rapidly on this trend. With the use of a smartphone, we can now communicate and have interactions with each other from almost any part of the world, whether we are at home, work etc, or are on the move. This has resulted in our day to day life and communication between one and other to become much easier and more convenient than ever before. In addition, digital methods of communication can be utilised to connect with business partners and clients around the world (Alikhasi et al., 2018)

1.6 Communication in Dentistry

Communication within the field of dentistry is also of incredible significance. There are several different aspects to communication in dentistry including the interactions between the dental clinician and the patient, and the dental clinician with the dental technician. Effective communication between the dental clinician and their patients can be terribly useful for the dental team as well as the patient. It also ensures that patients are able to make informed decisions and are aware of the procedure of their treatment process at all times. Effective communication between the dental clinician and patient is also connected with increased efficiency and diagnosis that are highly accurate, improved treatment outcomes, high patient satisfaction and less likelihood of complaints from patients (Afsharzand et al., 2006). The communication between the dental clinician and the dental technician is also of significant importance as it can determine the quality of the treatment provided to patients. Dentistry as a field is developing at a very rapid rate and at the same time, the patients' general knowledge and needs are increasing at a fast pace. Therefore, this demands an interactive relationship and adequate communication between the dental clinician and the dental technicians to attain successful results (Alsheikh, 2012). The General Dental Council (GDC) expresses that all dental professionals must communicate in a clear and effective manner with all other dental team members in a way that is in the patient's best interest. They likewise impose that dental training expects undergraduate students to develop a rigorous comprehension of the significant importance of communication within the dental team (Parry et al., 2014). As conveyed by the British society for the study of prosthetic dentistry, effective communication and a steady connection between dental clinicians and dental technicians is a critical requirement for good quality restorative work including technical procedures,

beginning with the transfer of the data regarding the design intended for appliances. To enable this, the two dental professionals (dental clinician and dental technician) must be eager to communicate adequately with one another (Radhi et al., 2007). Nonetheless, inadequate communication between the two dental professionals has demonstrated to be a significant reason for the failure in attaining this aim (Alsheikh, 2012). As of now, it has been discovered that there is poor communication between dental clinicians and dental technicians which requires the enhancement and improvement of communication at all stages, for example at training and professional practice level. It has been shown that communication problems mainly include an absence of data regarding prosthesis design and tooth shade (Afsharzand et al., 2006). Currently, the main communication methods used between the dental clinician and dental technician include written and digital communication (Hatzikyriakos, 2006).

1.6.1 Written communication in Dentistry

Written communication is a very common method of communication between dental clinicians and dental technicians in daily routine. In practice, the dental clinician fills in the work authorisation form (Fig 1.6.1.1) which should include design diagrams and handwritten instructions to order a laboratory work from a dental laboratory chosen by the dental clinician (Colombo, 2013). The dental clinician's duties are not only to supply the dental technician with instructions which are clearly written, but also to take precise impressions and send it to the dental technician. To take such impressions, the dental clinician should use a dimensionally stable elastomeric material with the use of a special or a modified stock tray. Such impressions must also undergo appropriate infection control measures prior to the impression being sent to the dental technician (Alsheikh,

2012). When delivered to the dental laboratory, the dental technician should then create the prosthesis as described by the guidelines provided on the work authorisation form by the dental clinician (Tulbah et al., 2017).

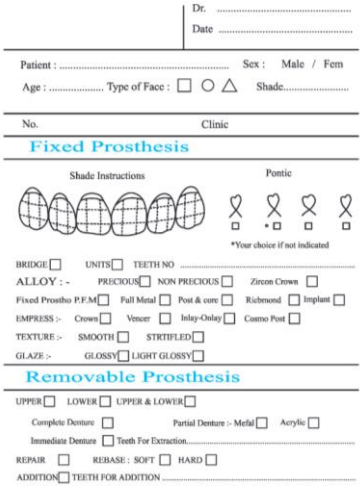

Dr. .....
Date .....
Patient : ..... Sex : Male / Fem
Age : ..... Type of Face : ☐ ○ △ Shade.....
No. Clinic
Fixed Prosthesis
Shade Instructions
Pontic
*Your choice if not indicated
BRIDGE ☐ UNITS ☐ TEETH NO .....
ALLOY : - PRECIOUS ☐ NON PRECIOUS ☐ Zircon Crown ☐
Fixed Prostho P.F.M ☐ Full Metal ☐ Post & core ☐ Richmond ☐ Implant ☐
EMPRESS :- Crown ☐ Vencer ☐ Inlay-Onlay ☐ Cosmo Post ☐
TEXTURE :- SMOOTH ☐ STRTIFLED ☐
GLAZE :- GLOSSY ☐ LIGHT GLOSSY ☐
Removable Prosthesis
UPPER ☐ LOWER ☐ UPPER & LOWER ☐
Complete Denture ☐ Partial Denture :- Metal ☐ Acrylic ☐
Immediate Denture ☐ Teeth For Extraction.....
REPAIR ☐ REBASE : SOFT ☐ HARD ☐
ADDITION ☐ TEETH FOR ADDITION .....

Fig.1.6.1.1 Example of a dental work authorisation form (Alshiddi et al., 2014).

A work authorisation form ought to be clear and provide all the required information needed in a thorough manner to manufacture biomechanically sound appliances. It must also be effectively comprehended by the dental technician to make the manufacturing process easier and more error free. Inadequately filled out work authorisation forms can result in prostheses that are improperly planned which can in turn cause damage to the patients' remaining oral structures (Owall et al., 2015). Nonetheless, appropriately completed work authorisation forms can make the fabrication procedure of appliances a lot less demanding and play a notable role in the overall quality of the appliance. It can also reduce the possibility of remakes or delays in the provision of the appliances (Parry et al., 2014).

1.6.2 Digital Communication in Dentistry

Dentistry as a field is continuously undergoing development in regard to many aspects. The wide drift of digital technologies in the field of dentistry started in the early 1990s where digital radiography and the earliest versions of intraoral scanning and computer-assisted design and computer-assisted manufacturing (CAD/CAM) crowns were established (Friedman, 2014), (Masri, 2015). The ride of Cone Beam Computed Tomography (CBCT) started a next wave of enthusiasm because three-dimensional images of the craniofacial area were able to provide new benefits in the treatment and diagnosis procedures. Therefore, it is of clear nature that digital dental technology has brought about many different benefits to the field of dentistry, but these can be summed up under four major categories. The first benefit is the enhanced communication. The clarification made in the communication in dentistry has provided major improvements with the use of electronic patient records. This now enables clarified exchange of data between the dental clinician, patients, the laboratory dental technicians and third-party stakeholders. Such digital records can also enable trade as well as improve and increase the accuracy of it. Additionally, using photographs to represent intraoral conditions through the use of digital radiographs have now raised the exchange of information to all dental team members and patients. Three-dimensional imaging technology with the use of radiographic or surface scans have also made improvements to the diagnosis and treatment planning procedure as well as communication between dental clinicians dental laboratory technicians and patients. The next improvement is the enhancement made in quality. In addition, the computerisation of information positively impacts quality control measures. This multilevel enhancement in quality also makes a significant improvement

to the workflow, planning and the accuracy of data. Software can also assure the entries of data as well as enhance decision-making. Furthermore, the intraoral scanning of tooth preparations that are looked at in high contrast has enlarged fields on a computer screen and is usually available for patients to see. This enables an immediate alteration to be made which can contribute to clinical improvement involving iteration (Paula et al., 2018).

1.7 Prosthesis Design Communication in Dentistry

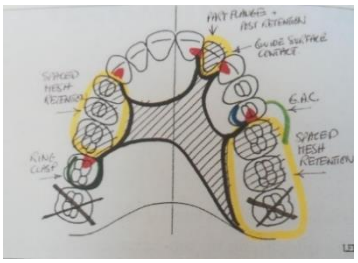
To create a prosthesis, for example a removable partial denture (RPD), the prosthesis ought to be fittingly designed and this design should be adequately communicated by the dental clinician to the dental technician (Davenport et al., 2000). An adequate level of communication regarding prosthesis design features between the dental clinician and dental technician has long been found to be a crucial contributing factor to the manufacturing of removable and fixed prostheses which are high in quality (Alsheikh, 2012). This precise communication also plays a big role in achieving highly aesthetic restorations accepted by patients (Alshiddi, 2014). For example, prosthodontics is an element of dentistry which requires a huge amount of teamwork between the dental clinician and dental technician to manufacture prostheses with an adequate level of function, aesthetics and fit. Effective and adequate communication between the two dental professionals is also of high importance due to the reason that in the majority of cases, dental technicians are in a completely different location and also never have a face to face interaction with the patient (Berry et al., 2014). Therefore, the quantity and quality of the clinical patient information they receive depends purely on how much of it and how thoroughly it is communicated to them by the dental clinician. As expressed by the "English Society for the Study of Prosthetic Dentistry: Guides to measures in

prosthetic dentistry", the responsibility of designing a prosthesis is on the dental clinician and not the technician (Aslam et al., 2015). Therefore, if the communication regarding design information from the dental clinician to the dental technician is insufficient, it can result in the provision of a prosthesis which possesses minimum reference to the basic clinical data. This can increase the chances of designing a prosthesis which is very poorly planned that can inflict pain and damage to the oral tissues and even embarrassment to the patient due to faulty aesthetics (Tulbah et al., 2017). Hence, adequate communication between the two dental professionals is of major importance and significance, particularly with respect to the design of the prosthesis fabricated (Alshiddi, 2014). The issues of inadequate transfer off design information are not new to dentistry. Initially, they were indicated more than three decades ago and have been demonstrated in many different countries around the world e.g. the United Kingdom. This problem appears to relate to both fixed and removable prostheses and has been assigned to financial and educational problems (Alsheikh, 2012).

1.7.1. Prosthesis Design via written communication

As mentioned earlier, the production of prosthesis for example RPDs requires the precise design of it which should to be communicated adequately between the dental clinician and the dental technician. This can be done by means of design diagrams on work authorisation forms which must present the number and position of supporting rests, major /minor connectors that are associated with rests and proximal plates. If the diagram is of poor quality, misinterpreting, inappropriate positioning and shaping of the different components can be a possibility (Davenport et al., 2000). The dental clinician should also draw retentive meshwork in the spaces which are edentulous, major connectors, direct

retainers in addition to outlining indirect retainers [Fig 2.1.7.1] (Mosharraf, 2017). As a result of an absence of a universally agreed colour code, agreements between the dental clinician and dental technicians on the significance of any code is of high importance. An example of this is a system with its foundation being based on the function of the RPD components. The colour red represents support, green represents retention, blue represents bracing/reciprocation and black represents connection.



(Davenport et al., 2000) Fig.2.1.7.1 Example of an RPD design diagram on a work authorisation form.

1.7.2 Prosthesis design via digital communication

The dental industry is realising that eliminating segment of the human element in restorative procedures may result in outcomes which are more reliable and predictable. In the meantime, the technologies used to accomplish this aim can likewise help improve communication between the dental clinician and the dental technician. Within last decades, different technology-based communication tools, e.g. Computer-aided design (CAD) and engineering systems which are aided by the computer, have evolved to assist with the process of development of products to minimise the requirement of physical prototypes as well as time and costs (Colombo et al., 2013). As a whole, digital dentistry constitutes of the wide range of complex technologies that put the communication, fabrication, provision and documentation of dental treatment under the umbrella of

algorithms which are computer-based. It starts with records which are patient-based e.g. visual and unified radiologic photos accumulated into business as well as planning software and documentation. Images which are three-dimensional and based on photographic, radiographic and surface scanning data have also made it possible to capture the diagnostic and design prostheses information which can be fabricated by computer numeric control (CNC) systems. Regardless of how thorough the dental clinician is in giving the dental technician the design details for a prosthesis e.g. an RPD, there can still be a possibility that with the written form of communication, the dental technician will still sometimes require additional information or clarification. The computerisation of dental practices and the development of appropriate knowledge-based systems have the potential to bring about superb benefits for advancing this fragment of dental consideration. Colour annotated design diagrams for RPDs with superb quality can be immediately created utilising a computerised knowledge-based system. The design expertise merged in the software will have an automatic kickback if a mistake is made and guides the user to an adequate design resolution. This means that errors can be easily eliminated in the clinical information provided by the dental clinician prior to being communicated to the dental technician. The advancement of such computerised RPD frameworks likewise brings about the possibility of online discussions between dental clinicians and dental technicians regarding RPD plans by means of the Internet. This category of tele-dentistry can be a worthy new communication tool between these two dentals professionals (Davenport et al., 2000).

Another form of digital means of prosthesis design communication is digital impressions such as intra oral scanners (IOS) and CAD-CAM. IOS enables the dental clinician to take an advancement of computerised images that are then transferred onto to a milling center. While the milling of the model is being carried out, the images are then sent to the dental technician where restorations are designed and milled. These days, CAD-CAM and IOS provide less demanding treatment planning, acceptance of cases, minimised operative time, diminished treatment times and of course, enhanced communication between the dental clinician and dental technician (Mangano et al., 2017). The regularly overlooked segment of the patient record laboratory information (restoration fabrication information) is likewise becoming progressively digital. Nonetheless, the integration of digital methods for the creation and transfer of this intraoral data is a lot less prevalent than for the forgoing data (Ender et al., 2011). However, many dental professionals have now implemented digital measures in to their dental offices, including the use of digital patient records. As a matter of fact, an estimated 90% of dental surgeries are now equipped with and are using some form of digital software for patient records, with 71% using digital radiographs (Jansen, 2018).

1.8 Shade Communication in Dentistry

The initial step for achieving clinical success in cosmetic and aesthetic dentistry is correctly identifying the tooth shade required to reproduce the shade that most precisely matches that of the natural remaining dentition. This information must then be accurately communicated to the dental technician. In addition, prosthetic dentistry will only be able to attain adequate outcomes under the condition that the dental restorations are aesthetically pleasing. Hence, the shade of the natural dentition must be accurately

dictated, and this is elementary as well as being of high importance for achieving precise results. It has also been found that the majority of the obstacles that surface in aesthetic restorations are correlated with matching the shades of these restorations to that of the natural dentition. Attaining an accurate colour match in dentistry is dependent on various visual examinations that are often communicated between the dental clinician, patient, and dental technician. When recovering teeth in the dental surgery, colour matching of materials with the natural dentition is usually carried out with the use of a shade guide. Shade guides are conventional models which consist of different shade tabs established on the colour allocation of the natural dentition. Visual judgment of colour with the use of shade guides is the most common technique for shade-matching in dental settings. However, due to the precision of visual shade taking technique being only 40-60%, many complications have occurred in the communication between dental clinicians, dental technicians and patients. To solve such issues, the use of digital devices for shade matching have started to become more prevalent in dentistry as a field. The devices which are utilised most often are digital cameras, colorimeters and spectrophotometers. Such devices have been researched in various studies to test how accurate and reliable they are (Kim et al., 2018).

A standout amongst the most bothersome situations a dental clinician can come across is intently matching the colour of an anterior restoration to that of the remaining natural dentition. In a perfect world, both dental professionals (dental clinician and dental technician) ought to be available in the dental surgery to try and closely match the tooth shade to the remaining dentitions. However, most of the time, this isn't the situation. The extra clinical data which the dental clinician ought to give regarding the tooth shade is the

patient's age and racial background as well as the length of their lips (this can make an impact on the patient's smile line) (Bahannan, 2014).

1.8.1 Shade Communication via written communication

In the case of shade communication via written communication, work authorisation forms can be used to transfer the required relevant information. The minimum information required on the work authorisation forms is an individual shade which should refer to the central segment of the tooth. On the work authorisation forms, the clinician should also state whether all teeth have a similar colour and value, whether there is graduation of colour/value and whether there are any clear-cut regions which are translucent. A drawing of a tooth split into three segments (incisal, centre, cervical) is also needed. The other required information includes the following: the hue of the dentine, the shade of the distinct regions and allocation of shades, the degree of the chroma, the value of enamel covering the dentine, particular distinctions on the shade allocation chart, translucency and its allocation and lastly white spots and stain areas (Bahannan, 2014). A diagram of a tooth split into 9 segments can also be included enabling specifications of multiple shades which can be highly beneficial for the dental technician, in particular regarding the production of ceramic anterior dental crowns. For a progressively refined shade taking, each segment can be inspected individually. For example, by assigning a cervical, incisal and overall basic shade as well as individual characterisation, the dental technician can fabricate a crown which intently matches the patient's remaining natural dentition. There is also additional information regarding craze lines, opacities, translucency and other surface characterisations which can be included in a tooth map (Lichter et al., 2000). This may come with extra information with regards to surface finish, staining or defects. There

may likewise be photos and study casts to assist with communicating the shade and surface texture to the dental technician. In such cases, the most prevalent method of shade matching is the visual shade matching technique, where a standard shade from a dental shade guide is contrasted and corresponded with that of the patient's remaining natural dentition. However as mentioned earlier, the visual shade selection can differ relying upon the dental clinician's shade observation skills, light conditions, background colour of the tooth and the shade guide utilised. Hence, because of the dental technician not having direct contact with the patient, communication with the dental surgery can become difficult. This is because the dental technician has to work off of the dental clinician's written prescription provided on the work authorisation forms and based on the shade guide utilised (Vinay et al,2011).

1.8.2 Shade communication via digital communication

As briefly mentioned above, the unreliability of the visual shade selection method can be overcome with the utilisation of shade matching devices which are technology-based (Vinay et al., 2011). There are now shade taking devices which are designed to help dental clinicians and dental technicians in attaining exact details and control of tooth shading such as digital cameras, spectrophotometers and colourimeters (Rosenstiel et al., 2006).

1.8.2.1 Digital cameras

Currently, digital photography is the fastest and most effective means to start utilising digital technology in order to enhance the communication between dental clinicians and dental technicians. It enables the dental clinician to capture images of all stages of treatment and transfer them to the dental technician (Griffin, 2009).Presently,

most email systems enable the transfer of messages up of to 10MB at once and numerous messages can be sent if all of the pictures go over the 10MB boundary (Nash, 2006). Today, most dental clinicians are utilising digital cameras and sending prints which are compact with photos to the dental laboratory and some clinicians communicate by sending digital pictures over the web (Derbabian, 2008). Amongst different types of photos, colour photos can be an appropriate tool for communication between the dental clinician and dental technician. This is especially true in the case of communicating information such as shade comparison to surrounding natural dentition and underlying substrates. Relative spread of enamel staining, intensity of the characterisations, the diverse levels of translucency and opacity in the incisal edge can likewise be communicated to the dental technician through the utilisation of digital cameras to take photos. Additionally, black and white photos can provide a visual description of surface texture as well as a comparison of the value. Through such photos, the position of the incisal edge, as well as the alliance of the provisional and final restorations to the contours of the horizontal plane and the lower lip can also be evaluated. Notes and comments can likewise be sent by the dental clinician with the taken photographs to communicate key features, for example shading, shape, alignment etc. This can lead to the fabrication of restorations which exhibit maximum reference to the clinical data with brilliant aesthetics and function (Terry et al., 2008).

1.8.2.2 Spectrophotometers

A spectrophotometer is a digital device which quantifies the extent of evident beaming energy which is reproduced by an item one wavelength at a time for every value, hue and chroma existent in the whole evident range. These devices can be utilised to

increase quantitative colour data for a certain restricted zone. However, they do not have the capability to provide image information. The little opening of the devices may likewise not be able to accurately detain the true shade for the surfaces of curved tooth/teeth. Spectrometers also utilise intensity histograms or mean values to point out the shade region for designating colour and overlook the geometrical allocation for pointing out the shade region of colour within the area. However, the Vita EasyShade (fig. 3.8.2.2), is a spectrophotometer for tooth shade matching and Crystaleye (fig. 4.8.2.2), (a new spectrophotometer) is an extremely precise dental system which assesses colour and provides very exact colour assessment (Li. et al., 2015)

Fig.3.8.2.2 Vita EasyShade (Knezovic et al., 2015).

Fig.4.8.2.2 Crystaleye (a new spectrophotometer) (Li. et al., 2015)

1.8.2.3 Colourimeters

Colourimeters are another example of digital shade taking devices which have the capability to quantify the tooth shades of various regions and focus along a line on the outer surface of a tooth. While putting the tip of the probe in close contact to the surface of the tooth, a measurement can be made. The demonstration component to which the probe adheres to includes a microprocessor and provides control, display and data

interface to the person operating the device. This device in particular is appropriate for determining the shade of teeth in a dental clinician's office for the fabrication of dental prostheses which accurately match with the shade of natural dentition. It must be noted that filter colorimeters are viewed as inferior to scanning devices like spectrophotometers as they are not able to match the basic observer functions. Nonetheless, due to being quick and consistent, these devices can still be utilised to carry out quality control (Brewer et al, 2004).

1.9 Aim and research Hypothesis

Currently, there is a gap in literature regarding the comparison of different methods of communication used between dental clinicians and dental technicians and the impact on dental appliance provision. The aim of this literature review was to compare written and digital means of communication between dental clinicians and dental technicians and examine its effect on the dental appliances constructed. The hypothesis of this literature review is that digital communication between dental clinicians and dental technicians is the effective method which leads to better appliances construction.

2.0 Materials and Methods

A literature review search was performed using databases such as PubMed, ScienceDirect, WileyOnlineLibrary and Discover Bolton. Also, the keywords used included the following: communication, dentist, technician, written, digital. The inclusion/ exclusion criteria used to include or exclude the retried scientific journal articles from this research are as shown in table 2.1. The study selection procedure included of first reading the title and abstract to assess whether the area of research is covered in the article or

not and also to see if the inclusion criteria were met. Next, the full manuscript was read, and the papers were chosen accordingly. A total of 64 journal articles were retrieved from the searches carried out with the databases. Full-text evaluation was then applied to these articles. After evaluating the inclusion and exclusion criteria, 15 articles were excluded. Accordingly, 49 articles published between 1960 and 2019 were included in this literature review. In addition, 5 books (1 hard copy and 4 online books) were used.

Table 2.1 Inclusion and exclusion criteria

Inclusion criteria

- Articles in English
- Articles written from the 1960 to 2018
- Survey articles
- Literature review articles
- Systematic review articles
- Human studies

Exclusion criteria

- Articles in any other language other than English
- Articles written before the year 1960

The table above states the inclusion and exclusion criteria used to include or exclude journal articles.

Table 2.2 Search A (PubMed)				
Date	***Database*** ***Keywords***	***Number of results***	***Number of results after reading the title***	***Number of results after reading the abstract and conclusion***
15/11/18	PubMed Communication AND dentist AND technician	146	27	7

Table 2.3 Search B (PubMed)				
Date	***Database*** ***Keywords***	***Number of results***	***Number of results after reading the title***	***Number of results After reading the abstract and conclusion***
10/12/18	PubMed Written AND prosthesis AND design AND communication AND dentist AND technician	4	3	1

Table 2.4 Search C (PubMed)				
Date	***Database*** ***Keywords***	***Number of results***	***Number of results after reading the title***	***Number of results After reading the abstract and conclusion***
12/11/18	PubMed Photographic AND shade AND selection AND Dental, photography	9	7	6

Table 2.5 Search D (PubMed)				
Date	***Database*** ***Keywords***	***Number of results***	***Number of results after reading the title***	***Number of results After reading the abstract and conclusion***
16/12/18	PubMed Digital AND intra oral scanners	18	12	7

Table 2.6 Search E (PubMed)				
Date	***Database*** ***Keywords***	***Number of results***	***Number of results after reading the title***	***Number of results After reading the abstract and conclusion***
3/01/19	PubMed Spectrophotometric AND shade AND selection	10	8	4

Table 2.7 Search F (PubMed)				
Date	***Database*** ***Keywords***	***Number of results***	***Number of results after reading the title***	***Number of results After reading the abstract and conclusion***
11/01/19	PubMed Digital AND impression AND conventional AND method	28	11	1

Table 2.8 Search G (PubMed)				
Date	***Database*** ***Keywords***	***Number of results***	***Number of results after reading the title***	***Number of results After reading the abstract and conclusion***
15/01/19	PubMed Removable AND partial AND prostheses AND communication	109	10	2

Table 2.9 Search A (ScienceDirect)				
Date	***Database*** ***Keywords***	***Number of results***	***Number of results after reading the title***	***Number of results After reading the abstract and conclusion***
20/01/19	ScienceDirect Written AND Prescriptions AND Dental Laboratories AND dentist	576	10	4

Table 2.10 search B (ScienceDirect)				
Date	***Database*** ***Keywords***	***Number of results***	***Number of results after reading the title***	***Number of results After reading the abstract and conclusion***
3/02/19	ScienceDirect Communication AND technology AND current AND new age AND dentistry AND dentist AND technician	162	15	1

Table 2.11 Search A (WileyOnlineLibrary)				
Date	***Database*** ***Keywords***	***Number of results***	***Number of results after reading the title***	***Number of results After reading the abstract and conclusion***
07/02/9	WileyOnlineLibrary Aesthetics AND shade AND communication AND dentist AND technician	321	10	2

Table 2.12 Search A (Discover@Bolton)				
Date	***Database*** ***Keywords***	***Number of results***	***Number of results after reading the title***	***Number of results After reading the abstract and conclusion***
25/1/19	Discover @ Bolton Written AND digital AND Communication AND between AND dentist AND office AND dental AND laboratory	270	10	3

Table 2.13 Search B (Discover@Bolton)				
Date	***Database*** ***Keywords***	***Number of results***	***Number of results after reading the title***	***Number of results After reading the abstract and conclusion***
9/01/19	Discover @ Bolton Designing AND removable AND partial AND denture AND framework	346	9	2

Table 2.14 Search C (Discover@Bolton)				
Date	***Keywords***	***Number of results***	***Number of results after reading the title***	***Number of results After reading the abstract and conclusion***
7/01/19	Discover @ Bolton Shade AND selection AND communication AND colour AND science AND dentist AND technician	150	9	4

Table 2.15 Search D (Discover@Bolton)				
Date	***Database*** ***Keywords***	***Number of results***	***Number of results after reading the title***	***Number of results After reading the abstract and conclusion***
26/12/18	Discover @ Bolton Communication AND dentist AND technician AND fixed prosthesis	686	14	1

Table 2.16 Search F (Discover@Bolton)				
Date	***Keywords***	***Number of results***	***Number of results after reading the title***	***Number of results After reading the abstract and conclusion***
22/12/18	Discover@ Bolton Digital AND communicatio n in dentistry AND Dentist AND Technician	548	36	2

Table 2.17 Excluded studies after complete reading of the text and reason for exclusion.

Study, Year	**Reason for Exclusion**
Touchstone et al., 2010	Not specific to the effects of digital communication on appliance manufacture
Zimmermann et al., 2015	Not specific to the effects of digital communication on appliance manufacture
Stanley.M et al,2018	Not enough detail on the effect of digital technology on the communication between dentists and technicians
Casaglia.A et al,2015	Repeated information, not enough detail about the effect of digital communication on appliance manufacture
Gholston.R, 1984	Not specific to communication
Wee. G et al,2006	Not specific to communication
Chu.S et al,2010	Not specific to communication
Lieth. R et al,2000	Repeated information
Kahng.L, 2006	Repeated information
Juszczyk. S et al,2009	Repeated information
Jesse. S, 2014	Repeated information
Farah.W et al,1991	Not available online
Francois.J, 2011	Repeated information
Parkash.H, 2016	Repeated information
Burgt.V et al, 1990	Not specific to communication

3.0 Results

The results of this literature review suggest that more research articles support the effectiveness of digital methods over written methods of communication. These findings can assist dental clinicians and dental technicians in incorporating more digital means of communication in their work routine to allow a more precise transfer of information between the dental office and dental laboratory. This can in turn lead to the provision of high-quality dental appliances. The table below represents the retrieved and used studies which had the most significant impact on the overall findings and conclusion of this literature review.

Table 3.1 Studies which contributed the most to the overall drawn conclusion.				
Authors	**Year of publication**	**Type of article**	**Title**	**Research conclusion**
Hassan et al	2017	Pilot clinical study	A digital approach integrating facial scanning in a CAD-CAM workflow for complete-mouth implant-supported rehabilitation of patients with edentulism: A pilot clinical study.	Technicians who usually only see photographs of the patient immensely benefitted from the virtual clinical evaluation, which led to improved patient-dentist-laboratory communication.
Mangano et al	2017	Literature review	Intraoral scanners in dentistry: a review of the current literature	IOS are time-productive and simplify clinical procedures for the dental clinician, wiping out plaster models and permitting better communication with the dental technician and with patients.
Schoenbaum	2011	Literature review	Technician collaboration in the	Digital technology has completely reshaped the abilities of the dental team to communicate across distances at a level that was

			Digital age: enhancing outcomes through Photography, teamwork, and technology.	previously only possible when all members of the team practiced within the same physical location.
Haj-Ali et al	2011	Survey	Dental Laboratory Communication Regarding Removable Dental Prosthesis Design in the UAE	Regardless of progress in dental health administrations in the UAE which is one of the quickest developing nations on the planet, the quality of written prescriptions for prosthesis design was found to be poor.
Lynch	2005	Survey	Quality of written prescriptions and master impressions for fixed and removable prosthodontics: a comparative study.	A high extent of written instructions to dental laboratories with respect to manufacture of chrome-cobalt RPDs contain no reference to the mentioned design factors.
Berry et al	2014	Survey	Communication methods and production techniques in fixed prosthesis	There are continuing communication and teamwork issues among dental clinicians and dental technicians in regard to shade communication through work authorisation forms.

			fabrication: a UK based survey. Part 1: Communication methods.	
Radhi et al	2007	Clinical study	Quality of written communication and master impressions for fabrication of removable partial prostheses in the Kingdom of Bahrain.	Written methods of communication between the dental clinician and dental technician often fails to provide the dental clinician with the necessary information required to manufacture a high-quality dental prosthesis
Afsharzand et al	2006	Survey	Communication between the dental laboratory technician and dentist: work authorization for fixed partial dentures	There are still ongoing errors in the communicated information through work authorisation forms regarding such information.

4.0 Discussion

From the conducted research, it can be suggested that the hypothesis ‘’ digital methods of communication between dental clinicians and dental technicians is the effective method which leads to better appliance construction’’ can be accepted.

4.1 Written Communication in dentistry

A study by Alsheikh (2012) assessed the quality of communication between dental clinicians and dental technicians through work authorisation forms. To obtain results, 200 questionnaires were distributed to dental technicians and 136 were received. The results showed that half of the written instructions (49.6%) were viewed as "clear". This could suggest that written communication can be viewed as a genuinely acceptable means of communication between dental clinicians and dental technicians. However, out of the 49.6%, 34% of the dental technicians required clarification regarding some of the written instructions. This demonstrates that deficient written instructions and communication between the dental clinician and dental technician may be due to the reason that often, the dental clinician relies on the dental technician to fabricate the prostheses in a certain way and design. It could likewise be because of inadequate undergraduate training in writing laboratory instructions. Therefore, it was concluded that overall, the quality of the written instructions for fixed and removable prosthodontics was deficient. This in turn led to the provision of appliances which did not exhibit maximum reference to the clinical patient data. The recent date of the study suggests that the results are up to date and therefore adds to the reliability value of the overall findings. Also, the fairly high number of respondents demonstrates the reliability of the results as it suggests the results can be generalised.

4.1.1 Prosthesis Design communication via work authorisation forms

A number of different studies conducted in Europe and the US have observed low quality communication between dental clinicians and dental technicians in regard to cast RPD manufacture. They demonstrated that the quality of the work authorisation forms provided by the dental clinician and manufacture of cast RPDs by dental technicians often failed to follow critical requirements. In a study by Radhi et al. (2007), where six private dental laboratories in Bahrain participated, it was demonstrated that 57% of the cast RPD instructions provided on the work authorisation forms required the dental technician to design the prosthesis with only 1% giving all the required design variables. The results also showed that the quality of the provided written instructions from the dental clinicians to dental technicians for the production of RPDs was not adequate. Hence, the results suggest that written methods of communication between the dental clinicians and dental technicians often fails to provide the dental technicians with the necessary information required to manufacture a high-quality dental prosthesis. The old date of the study suggests that the findings are now out of date and reduces the reliability value of the findings. Also, the number of laboratories included were low. Therefore, the overall findings may not be an accurate representation of the level of communication between the two dental professionals in the whole of Bahrain. The laboratories were also all private which means non-private laboratories were not considered and this again takes away from the overall reliability value of the findings.

Additionally, in a study by Haj-Ali et al. (2011) carried out in the United Arab Emirates (UAE), 21 laboratories completed a questionnaire and were requested to examine RPD cases made in the past 2 months. They were also requested to recognise

steps taken by the dental clinician and dental technicians prior to the fabrication of the framework. It was found that 84.2% of the dental clinicians often communicated through work authorisation forms, with 89.5% never or rarely providing details regarding RPD design. In addition, while 52.6% of the dental technicians agreed that it is the responsibility of the dental clinician to decide the final RPD design, 94.7% agreed that dental clinicians should depend on dental technicians for decisions regarding design making. Likewise, all of the 21 laboratories contacted in the study agreed that 100% of the dental clinicians once in a while or never sent surveyed diagnostic casts. Therefore, the findings of this study suggest that written means of communication between the dental clinicians and dental technicians fail to transfer the required clinical information from the dental office to the dental laboratory. Accordingly, it was concluded that the participating dental technicians (94.7%) believed that dental clinicians ought to rely upon dental technicians for decisions regarding design-making. However, this poor communication does not consider the legal duties of the dental clinician to manufacture cast RPDs based on mechanical and biological principles. Therefore, another conclusion which was drawn was that that regardless of the progress in dental health sector in the UAE which is one of the quickest technologically progressing nations, the quality of written prescriptions provided on work authorisation forms for prosthesis design was found to be poor. The recent date of this study demonstrates the high reliability value of the findings as it suggests that the findings are up to date However, the number of the contacted laboratories were low, which means that the findings cannot be generalised and are therefore takes away from the reliability value of the findings. In addition, these findings

are only limited to the laboratories in Bahrain, which further reduces the reliability value of the overall findings.

Also, in a study by Ghoneima et al. (2010) 210 questionnaires were handed out to 21 laboratories in Wales, Ireland and England. This was to collect information on how well dental clinicians and dental technicians communicate with each other through work authorisation forms (written means of communication). The instructions provided by the dental clinician were classified by the dental technicians as either apparent, deficient or neither. Dental technicians were also questioned if the dental clinicians ordered them to design the RPD. It was found that the quality of written communication was not sufficient which increased the danger of periodontal disease or caries for patients in addition to soreness/pain and annoyance with the provision of inappropriately designed RPDs. These results demonstrate a non-compliance to the legal obligations in providing patients with high-quality appliances. The fairly recent date of the study suggests that the findings are up to date and add to the reliability value of the results. Also, the laboratories contacted were in 3 different countries which adds to the reliability of the results as it is considers of the quality of communication in different areas. However, only 21 laboratories were included which can mean that the results cannot be generalised and takes away from the reliability value of the findings. Additionally, in a study by Lynch et al. (2005) the quality of written instructions given to dental laboratories for manufacture of chrome-cobalt RPDs in Ireland was examined for evidence of four design factors. These factors included the base layout of dentures, retention, support and the design of the connectors. Six hundred questionnaires were distributed, and there was a 75% response rate. The utilisation of diagrams was additionally analysed. It was found that

every one of the four design factors were evident in only 10% of instructions with 7% containing reference to three factors, 13% containing reference to two factors and 17% containing reference to a single factor. Additionally, there was an absence of design features in 53% and only 5% asked the dental technician to take responsibility for the prosthesis design. Lastly, it was found that only 7% of instructions incorporated diagrams. Accordingly, the conclusions from the conducted research were that a high extent of written instructions to dental technicians with respect to manufacture of chrome-cobalt RPDs presented no reference to the design factors stated on the work authorisation form. This can in turn lead to the provision of low-quality dental appliances. The old date of the study may suggest that the findings are now out of date which reduces the reliability value of the results. However, the high number of distributed questionnaires and response rate suggests that the results can be generalised, therefore, adding to the reliability value of the findings.

4.1.2 Shade communication via work authorisation forms

In a study by Berry et al. (2014) where work authorisation forms were the primary communication method, 782 questionnaires were distributed to the laboratories and 248 were received. The questionnaire aimed to explore the means of communication used between dental clinicians and dental technicians from the point of view of the dental technician. The questionnaire included questions regarding general information, means of communication, the disinfection process of the impressions, the techniques used for the production of the appliances, the process of matching the appropriate shade, team management and time management problems. It was discovered that the regularly missing piece of information from the work authorisation forms were the required tooth

shade. Seventy three percent of the respondents reported that an individual shade was chosen in more than half of the cases and 68% expressed that the dental clinicians allowed adequate laboratory time. However, 26% of laboratories expressed that they were either rarely or not at all included as a major aspect of the dental team. Hence, one of the major conclusions from the conducted research was that there are continuing communication problems between dental clinicians and dental technicians in regard to shade communication through work authorisation forms. The recent date of the study adds to the reliability of the findings as they are considered to be up to date. Also, the high number of distributed questionnaires and respondents suggests that the findings of the study can be generalised and are reliable. Likewise, Koodaryan et al., (2016) assessed the standard of written work authorisation forms for removable and fixed prosthesis in the city of Tabriz in Iran. Six hundred questionnaires were handed out to 15 dental laboratories which received removable as well as fixed prosthesis orders. The results demonstrated that data regarding the tooth colour, the area of the ceramic veneering and the design of the margin for fixed partial dentures were confirmed in 82.6%. Hence, the attainted results led to the conclusion that regarding shade communication, there was a generally high level of well communicated shade data. Nonetheless, work authorisation forms were generally not fully complete which may negatively impact the quality of prosthetic treatment. In addition, the required number of pontics was only stated in 41% and the design of the pontics was only stated in 11% of the work authorisation forms. Therefore, it was concluded that overall, the work authorisation forms were generally not fully complete and this can have a negative impact on the quality of the provided dental appliance. The recent date of the study adds to the reliability of the results

as it suggests that the results are up to date. However, this study was carried out in Iran, which may suggest that the findings apply to Iran only. The number of included laboratories is also fairly low which may mean that the results cannot be generalised and lack in reliability.

In addition, the findings from a literature review by Lichter et al. (2000) were that more often than not, laboratory work authorisation forms do not ask for adequate data from the dental clinician regarding the choice of the tooth shade process. This could be because there is not enough room on the work authorisation forms to enable this. This can in turn lead to the provision of dental appliances which lack in aesthetics. Therefore, dental laboratories ought to completely comprehend the requirement for shade matching. The attained results led to the conclusion that all work authorisation forms should incorporate adequate space to record data such as different shades of porcelain and opaque, and situation regions on the tooth. Work authorisation forms should also embody diagrams of the tooth with the aim that the dental clinician can draw useful notes on them (for example shade, translucency, staining, glaze and surface texture). The dental clinician ought to likewise be in contact with the dental technician at all times to ensure that they completely comprehend what is asked of them. Such techniques can allow the dental clinician to develop a stable relationship with the dental technician. However, the old date of the study may suggest that the results are no longer up to date and takes away from the reliability value of the overall findings. Furthermore. in a study by Afsharzand et al. (2006) a questionnaire was sent to dental technicians to determine the level of communication between dental clinicians and dental technicians in specific areas of the work authorisation forms for the fabrication of fixed partial dentures. The

questionnaire was distributed to the dental laboratory managers for 199 dental laboratories in total. The survey contained questions related to the clarity and thoroughness of the work authorisation forms as well as the extent of the provided patient information, the choice of materials for the prosthesis, the design of the prosthesis and shade description provided on the work authorisation forms. Out of the 199 laboratories which were contacted in this study, there was a 57% responded rate to the questionnaire. The findings suggested that there is a deficiency in communication between dental clinicians and dental technicians via work authorisation forms regarding the choice of the required shade for restorations, choice of margin and pontic design for the prosthesis. Hence, the results of the study led to the conclusion that there are still ongoing errors in the communicated information through work authorisation forms regarding such information. This study was conducted in 2006, therefore it can be suggested that the results may now be out of date and no longer reliable. However, the high number of the laboratories contacted means that the findings can be generalised and adds to the reliability value of the overall findings.

Nonetheless, in a study by Tulbah et al. (2017) the communication between dental clinicians and dental technicians via work authorisation forms for manufacturing fixed partial dentures (FPDs) was assessed in private dental laboratories as well as dental laboratories which belonged to the government in the city of Riyadh. The results showed that over 75% of dental clinicians included the restoration shade in the work authorisation forms, which was seen in 64% of the laboratories. It was also found that 75% the private laboratories presented this in comparison to 50% from the government laboratories. This suggests that work authorisation forms can be an effective tool for communication of tooth

shade between the dental clinicians and dental technicians. The recent date of the study suggests that the results are up to date and therefore adds to its overall reliability. However, the obtained results are limited to laboratories in Saudi Arabia as this is where the study was conducted. Therefore, this takes away from the reliability of the results.

4.2 Digital communication in Dentistry

In a review article done by Kalpana et al. (2018), the conducted research led to the conclusion that digital dental photographs as a method for exchanging clinical data are capable of bring laboratory cases nearer to the visualisation of the real patient. Having more data available at hand means that dental clinicians and dental technicians can offer better skills to a greater accuracy and achieve ideal restorative outcome with lifelike results for the patient. The recent date of the article suggests that the findings are up to date and add to the reliability value of the findings. Also, a high number of references were used in this review article, which again suggests that the findings can be relied on. Moreover, the conclusions of a literature review by Schoenbaum (2011) were that digital technology has significantly enhanced the abilities of dental clinicians and dental technicians to communicate over distances at an extent which was previously only attainable when the two dental professionals were present in the same location. Clear communication through digital means also enables the formation of pleased productive teams who work to the best of their ability to the patient's best interest e.g. the manufacture of high-quality dental appliances. The recent date of this literature review adds to the reliability value of the results obtained as it suggests that the findings are up to date.

4.2.1 Digital Prosthesis Design Communication

A pilot study by Hassan et al. (2017) evaluated a digital approach cooperating digital dental intraoral and extraoral facial scanning information to design and mill a CAD-CAM implant-retained prosthesis. The study included 10 patients who required complete-mouth rehabilitation. To acquire intra-oral records which were digital, optical scanners were used to reproduce the provisional prosthesis with the use of a scanner in the laboratory while extra-oral digital records were acquired by scanning the face with the use of a facial scanner. The impressions which were scanned as well as occlusal records were utilised to make a tooth arrangement which was virtual. They were then corresponded with the patient's 3-dimensional face scan to make a virtual examination stage in the clinical setting. It was found that using the digital approach majorly improved the communication between the dental clinician and dental technician especially regarding prosthesis design. Therefore, the results attained from the study led to the conclusion that technicians who usually see photographs of the patient vastly benefitted from the virtual clinical assessment, as this resulted in enhanced communication between the dental clinician, dental technician and the patient as well as enhanced appliance provision. The recent date of the study suggests that the results can be relied on as they are considered to be up to date. Also, in a literature review by Mangano et al. (2017), the results of the conducted research led to the conclusion that IOS are time-productive and make clinical procedures for the dental clinician much easier and simpler as well as eradicate the need for plaster models. They also enable improved communication with the dental technician and patients. However, it tends to be difficult to dictate intense margin lines in prepared teeth with the use of IOS. The present IOS are adequate and

precise for catching impressions for manufacturing a collection of prosthetic restorations such as crowns, fixed partial dentures, inlays / onlays etc. on both natural dentition and implants. In addition, they can be utilised for smile design and manufacturing of posts and cores, RPDs and obturators. However, to this date, no literature supports the utilisation of IOS in long-span restorations efforts with natural dentition or implants. The recent date of the literature review adds to the reliability value of the overall findings as it suggests that the obtained results are up to date.

Additionally, a study by Batisse et al. (2017) intended to demonstrate the procedure of designing RPD framework from an optical impression. The impression was transferred to the dental technician electronically. The manufacturing process of the RPD was carried out through CAD/CAM utilising laser fusion technology for the fabrication of the framework. It was found that the conventional fabrication of RPD is corresponded with mistakes from both the dental clinician and the dental technician. Hence, the use of optical impression and the digital chain could minimise the chance for mistakes and enhance the communication between the two dental professionals. However, currently optical impressions cannot record the combination of the tissue and cannot deliver impressions which are anatomo-functional. Hence, the results achieved from the conducted research led to the conclusion that the advancement of intraoral scans is also making way for appealing probabilities. Nonetheless, further studies are required to approve this procedure. A potential progression in the future could be the combination of simplified software enabling the RPD framework to be drawn prior to its transfer to the dental technician. These findings suggest that a digital method of transferring prosthesis design information can be an effective means of communication between the dental clinician and

dental technician. This study was conducted in 2017 which adds to the reliability value of the findings. This is because it suggests that the obtained results are up to date and relevant.

4.2.2 Digital Shade Communication

The aim of a study by Jarad et al. (2005) was to make enhancements to a technique based on digital imaging which was used to match the shade of restorations to natural dentition. They also aimed to compare the user's abilities by the use of this technique with that of the traditional one against a spectrophotometric technique. Shade guides (two) were used in this study, with nine shades being chosen from the first shade guide. The second shade guide was utilised to match the chosen shades and a digital camera was utilised to document the digital photos of the shade tabs in the shade guides used. Three duplicates of every shade of the nine chosen tabs were matched by the observers with a shade guide which was digital and supplied from the digital photos of the second shade guide on a computer screen. All the inspectors also matched the same shade tabs with the use of the traditional shade matching technique. The analysis demonstrated a massive difference between the traditional method and the computerised method with a 43% and 61.1% precise match. There were also major differences between observers in both methods for the conventional and computerised methods. Hence, the results of this study led to the conclusion that the abilities of the observers to match shades accurately was remarkably better when a computerised method was used in comparison to the use of a traditional method. Another conclusion drawn was that the digital camera can be used as a means of analysing tooth shades and transfer of such data between the dental clinician and dental technician. The high number of samples

used in the study adds to the reliability value of the findings as it means that the findings can be generalised. However, the old date of the study suggests that the findings may now be out of date and takes away from the reliability value of the findings. Additionally, a literature review by Chen. et al. (2012) evaluated 26 studies that made a comparison between the performances of different tooth shade taking techniques. Differences between instrumental and visual measurements were observed with matching the shade using a spectrophotometer being the most accurate. It was also found that even though visual shade matching can be inconsistent, it does not mean that this method is necessarily inferior to colorimetric measurement in regard to accuracy. However, further studies were required to enable a comparison between spectrophotometric and digital imaging techniques. This literature review was carried out in 2012 which suggests that the results are up to date, therefore adding to the reliability value of the findings.

In addition, Bahannan et al. (2014) compared the quality of the shade matching which was either visual or machine-aided in dentistry students. Altogether, 204 students took part in the study. The process of shade matching with the use of a spectrophotometer and 3D Master system was explained to them. In order to replace anterior teeth in the maxilla, the students chose the most ideal shade match with the use of each technique. It was found that 36.3% of the students who participated visually chose the true shade, and 80.4% achieved this with digital means. The level of experience and gender did not seem to impact visual shade selection; also, with the digital means, both genders equally understood how to use the machine and experience did not seem to impact the results. Therefore, the conclusion made from this study was that the shade matching device (digital means) were much better and effective than the conventional visual method for

the accurate determination of tooth shade. The findings also suggest that the digital means of shade selection can enable an enhanced level of communication between the dental clinician and the dental technician as clinical data can be precisely transferred. This can in turn lead to high-quality appliance provision. This study was carried out in 2014, therefore this demonstrates that the findings are up to date and reliable. Also, the high number of students who took part in this study adds to the reliability of the overall results. Moreover, Miyajiwala et al. (2017) investigated three different techniques utilised for shade selection (the use of a visual technique, the use of a spectrophotometer, and the digital photography method). A significantly higher rate of agreement among spectrophotometric and visual technique was found with higher degree of comprehension. It was found that the extent of agreement between spectrophotometric and visual shades detected a fair level of agreement. Major distinctions were also found in the proportion of ΔE (difference in the shade) more than and <2, between spectrophotometric and digital photography methods with more of <2 ΔE. Additionally, the level of agreement between shades determined with the use of a visual and spectrometer revealed the highest level of agreement with the A1 shade. The findings suggest that digital means of shade taking can result in improved appliance provision as they provide a much more reliable measure of shade selection and enable enhanced level of communication between the dental clinician and dental technician. The results attained from the conducted research led to the conclusion that the digital photography technique is a very reliable method for shade determination and communication between dental clinicians and dental technicians. The recent date of the study suggests the findings are up to date and therefore adds to the reliability value of the overall results.

Furthermore, Gehrke et al. (2009) investigated the reliability of digital shade matching devices and aimed to coincide the outcomes with the traditional shade analysis method. Tooth shade consensus of two digital shade matching devices were determined with the utilisation of a spectrophotometer and a colorimeter. The devices were compared, and experienced examiners observed 40 subjects under clinical settings. The results demonstrated that spectrophotometric shade determination is always capable of reproducing accurate tooth shades when compared to the conventional shade analysis technique. It can also be a valid inclusion in colour matching and enhance the accuracy of shade examination, communication between the dental clinician and dental technician and the fabrication of dental restorations. Nonetheless, the old date of this study suggests the findings may no longer be up to date and takes away from the reliability value of the overall results. In addition, the aim of a study by Alshiddi et al. (2015) was to compare the precision of shade determination with the use of a spectrophotometer to a conventional method using a shade guide for students who were either previously trained or not trained to do so. The student who had previously been trained were provided with a presentation and training activities on colour science and selection of tooth shade, while the students who had not been previously trained were not provided with any data or training activities. All student matched the colour of a tooth for eight test subjects with the use of both methods. Assessments were carried out to examine colour and value differences between the existing dentition and the shade taken by each method for students who were trained and students who were not. As a whole, the spectrophotometric method was found to be more accurate. It was also found that in general, students who were trained were more precise in matching tooth shade, utilising the visual method. They were

also better as a whole in matching the value visually than when a spectrophotometer was utilised. In addition, untrained students matched both the shade and the value more accurately when a spectrophotometer was used. The findings additionally suggest that the digital method of shade selection can also enable an enhanced level of communication between the dental clinician and the dental technician. This is because digital dental devices such as spectrophotometer were capable of providing accurate, reliable results. Hence, the conclusions drawn from the conducted research were that shade matching with the use of a spectrophotometric can be more precise than a conventional method. However, if one is trained and has knowledge about colour science and shade selection, it can have a major impact on the results. This study was carried out in 2015, which means that the results are up to date and therefore reliable.

Also, a literature review by McLaren et al. (2011) provided current viewpoints and information regarding the present technologies for shade-taking and the procedures accelerating this process. The results from the conducted research were that utilising all three methods (digital photographic, visual, and computerised) for shade selection has shown to be the most accurate method to dictate and finalise the exact shade. More essentially, it was found to be the best way for reproducing it with materials such as dental ceramics and composite. It was also concluded that using traditional and more progressive digital shade-taking together, enables dental clinicians to adequately communicate paramount shades to the dental technician to help avoid obstacles related to aesthetics in the restorative process. This would in turn lead to the provision of high-quality dental appliances. The recent date of the literature review suggests that the findings are up to date which means that the results can be relied on.

However, Ballard et al. (2017) assessed the students' shade-matching results when a spectrophotometer was used to investigate the satisfaction levels of patients, students and governing faculty personnel with the clinical shade-matching results. The study also aimed to investigate the clinicians' support for utilisation of the spectrophotometer to enhance aesthetic results. One hundred and three groups (each including, dental students and supervising faculty members of a university and patients) took part in the study. Utilising the clinical shade-matching result (ΔE clinical), spectrophotometer and laboratory shade-matching result (ΔE lab) were determined. The attained results demonstrated that both ΔE clinical and ΔE laboratory were outside the clinical agreeableness limit ΔE values when shade guides were utilised to create restorations. It was also found that characteristics of all the participants and restorations had very little to no impact on the ΔE clinical results. In general, clinical shade-matching results in this institution appeared to require further enhancements. Therefore, the findings suggest that digital means of shade assessment and communication may not always be the most beneficial and effective for the provision of high-quality dental appliances. The recent date of this study adds to the reliability of the obtained results as it suggests that the findings are up to date and relevant. Also, the high number of participants suggests that the overall findings can be generalised which again adds to the reliability value of the findings.

The limitations of the research carried out for this literature review included the limited variety of books available at the library which were related to the studied topic area. Also, several journal articles were not available online, therefore they could not be included in this literature review. However, from the conducted research, it can be

suggested that further research should be carried out into any new digital devices or techniques which can furthure simplify the transfer of clinical data between dental clinicians and dental technicians. This would also enhance the quality of the fabricated dental appliances even further.

5.0 Conclusions

From the conducted research, it can be concluded that effective means of communication between the dental clinician and dental technician is of significant importance as it can make a huge impact on the quality of the appliances provided for patients. It can also lead to higher acceptance of the appliances by the patients as the appliance would be fabricated with maximum reference to the attained clinical patient data. It can also be concluded that overall, the communication between dental clinicians and dental technicians is inadequate which requires the improvement in the methods of communication used by the two dental professionals. As a whole, written means of communication such as using laboratory written work authorisation forms appeared to result in more insufficient transfer of clinical patient data. The reason for this was that generally, the dental clinician did not include vital information needed for the dental technician to fabricate an appliance the way it would benefit the patient the most. This not only results in the increased chance of appliance refusal by the patient, it also increases the need for possible remakes and repairs. However, the use of digital means of communication between dental clinicians and dental technicians such as digital cameras and digital dental intraoral and extra oral facial scanners made a significant improvement to the exchange of clinical patient data and therefore the quality of appliances. Therefore, to ensure the provision of high-quality appliances, an adequate and reliable

communication method must first be chosen by the two dental professionals. These findings are of significant importance as they can assist dental clinicians and dental technicians in incorporating more digital methods of communication in their daily work routine. Not only would this maximise the quality and quantity of the communicated clinical patient data, it would also enhance the overall quality of the fabricated appliances.

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